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THE IMPACT OF THE ORGANIZATION OF THE WORKING DAY ON PRODUCTION EFFICIENCY IN THE LABORATORY OF PLANT TISSUE CULTURES

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Purpose: The aim of the study was to rate the employee's productivity on different work day organization and to indicate the most optimal work schedule.
Design/methodology/approach: For the research presented in this paper, strong literature review was done. We showed why human workforce is so important in tissue culture laboratory and why proper work organization is essential for increasing competitiveness of companies. Literature in the field of overtime work and short, elastic hours of work was also presented. Our research design checked effectiveness of work of ten employees of tissue culture laboratory in five different workday schedules. First combination was control and four other investigated influence of six hour work on main task in different arrangements on productivity. Data was statistically analysed with Kruskal-Wallis ANOVA. Productivity Index and Labour Productivity Index were also used for better results processing.
Findings: The highest employees productivity is concentrated in the middle of work day. In conventional eight hour workday, the highest productivity is just after fifteen minute break. Six hour workday has big potential in increasing work, especially when main task is not interrupted by other activities and when work starts at the beginning of workday.
Research limitations/implications: In future, research should be expanded on employees efficiency in work with bioreactor and costs analysis of plant production in such system.
Practical implications: Our results are directed to plant tissue culture companies and others where employees are essential and their work requires concentration during repetitive activities. We suggest solutions increasing work efficiency.
Originality/value: Our work presents hour after hour analysis of work efficiency in different workday organization in plant tissue culture company.

Keywords: day schedule, productivity, work organization, work effectiveness.

Category of the paper: Research paper.

1. Introduction

Employees are essential in many companies and they still cannot be replaced by machines in some professions. Mass production of *in vitro* plants in tissue culture laboratory is such a profession. It requires accuracy, precision and the ability to make the right decision. Tissue culture technology, for plant clonal propagation, was introduced in the mid 1960's (Thorpe, 2007). Although traditional methods have been around in commercial usage for more than 50 years, it has been automated to a small extent and then only in medium preparation and dosage. It is relatively easy because of the extremely developed dosing technology used in other industries. The only challenge is to maintain asepticity and the use of frequently occurring short series of media. Short media series occurs when a laboratory is not specialised in a narrow amount of plant species growing in the same medium. So offering a wide range of species causes difficulties and then an efficient human workforce is very important.

In vitro protocols for plant propagation are presented for many species. These protocols start from simple methods ranging up to advanced bioreactor production, but there is little information about productivity and the cost of plant propagation used within *in vitro* techniques. Taking into consideration the fact that *in vitro* laboratories are currently developing and increasing production, studies on cost calculation and cost reduction proposals should be carried out Souza et al. (2015), Chiachung Chen (2016), Saraswathi et al. (2016), Pożoga et al. (2019), focused on research in this field. The researchers describe variable costs of production or costs of total laboratory investments in certain species production. Still there is a lack of production of plants in bioreactor cost analysis. Very often the workforce is a considerable cost for production companies. Pożoga et al. (2019) indicated that 48% of variable costs of Paulownia tree (*Paulownia tomentosa* × *Paulownia fortunei* hybrid) *in vitro* production is connected with labour. According to Chiachung Chen (2016) labour is more than 60% of the total cost of production of orchid (*Phalenopsis)* plants. That is why studies on human workforce productivity should be provided. By increasing human productivity companies can achieve better results and decrease production costs. The increase, can be done in many ways. It can be stimulation using music (Lesiuk, 2005; Haake, 2011), light intensity (Karlikova et al., 2016), environmental quality and employee satisfaction (Vischer, 1989; Staw, Barsade, 1993; Garris, Monroe, 2005). Moreover Street et al. (2019) indicates that stress is also a crucial factor of productivity and labour cost reduction. Reducing stress among employees can significantly increase an enterprise's results.

The fast development of technologies, especially connected with communication, has created a '24-hour society' over the recent years. Employees are always ready to pick up the phone or answer an email when they have finished work. People spend evenings trying to achieve goals set by employer's. A sharp line between time of work and a time for relaxation is not so obvious nowadays. Very often people have to work overtime (Golden, 2012).

But how is this continuous readiness to work affect productivity? O'Conner, L.V. (1969) and Haneiko, J.B. and Henry, W.C. (1991) showed that working overtime brings a loss in efficiency. Firms see this issue and try to solve this problem. There are a lot of companies doing private research indicating that working fewer hours increases productivity. This can include working fewer hours in a day or working less hours during the week. Also flexible working hours can increase productivity (Kossek, Van Dyne, 2008; Kossek, Lee, 2008). It is also important to introduce shorter work conditions as stated in Parkinson's Law. It states that 'work expands so as to fill the time available for its completion' (Parkinson, 1955). This means that the closer we are to the deadline the higher productivity becomes. So duties on an eight-hour work day can be done faster. This can be achieved by properly planning work and encouraging employees and for sure this is worth some attention.

This study was conducted among ten employees of Plant Research Laboratories located in Warsaw, Poland. The employees were male and female within the age range of 20-35 and were responsible for different tasks in the laboratory. Research was repeated three times for each combination and each employee. The plant used in the experiment was an ornamental alternantera plant (*Alternanthera dentata)*.

The working day for the people responsible for transplanting of plants starts at 9 am and ends at 5 pm. Employees arrive a few minutes earlier to prepare for work. At 9 am they sit at their workplace, spray it with 70% ethanol solution and transfer 20 containers with a culture medium, 4 containers with mother plants, sterile paper plates, tweezers and scalpels to laminar flow hood. All these objects are prepared by a different person who is responsible for work organization, and not included in the study. There are always 3 pairs of tools. One pair of tweezers and scalpels is used for cutting plants, the second is in a glass bead steriliser and the third in an ethanol solution. Tools for cutting are changed after completion of transplanting of mother plants from one container. Hand used tools are transferred to a glass bead steriliser, hot tools from the steriliser are moved to ethanol and cool tools from ethanol can be used for further work.

Plant cultures are kept in polypropylene 350ml containers. The cutting of plants is done on a sterile paper plate.

The workplace is always organised in an optimal way. Tools, such as tweezers and scalpels, paper plates for cutting, containers with mother plants and containers with the medium are located near to each other and can be easily grabbed with a highly reduced possibility of contamination. All the equipment can be reached with body movement reduced to a minimum (Figure 1A). Chairs for employees are comfortable, do not cause back pain and are in accordance with the principles of health and safety at work. The LED lighting of the workplace used meets requirements. Employees work in gloves.

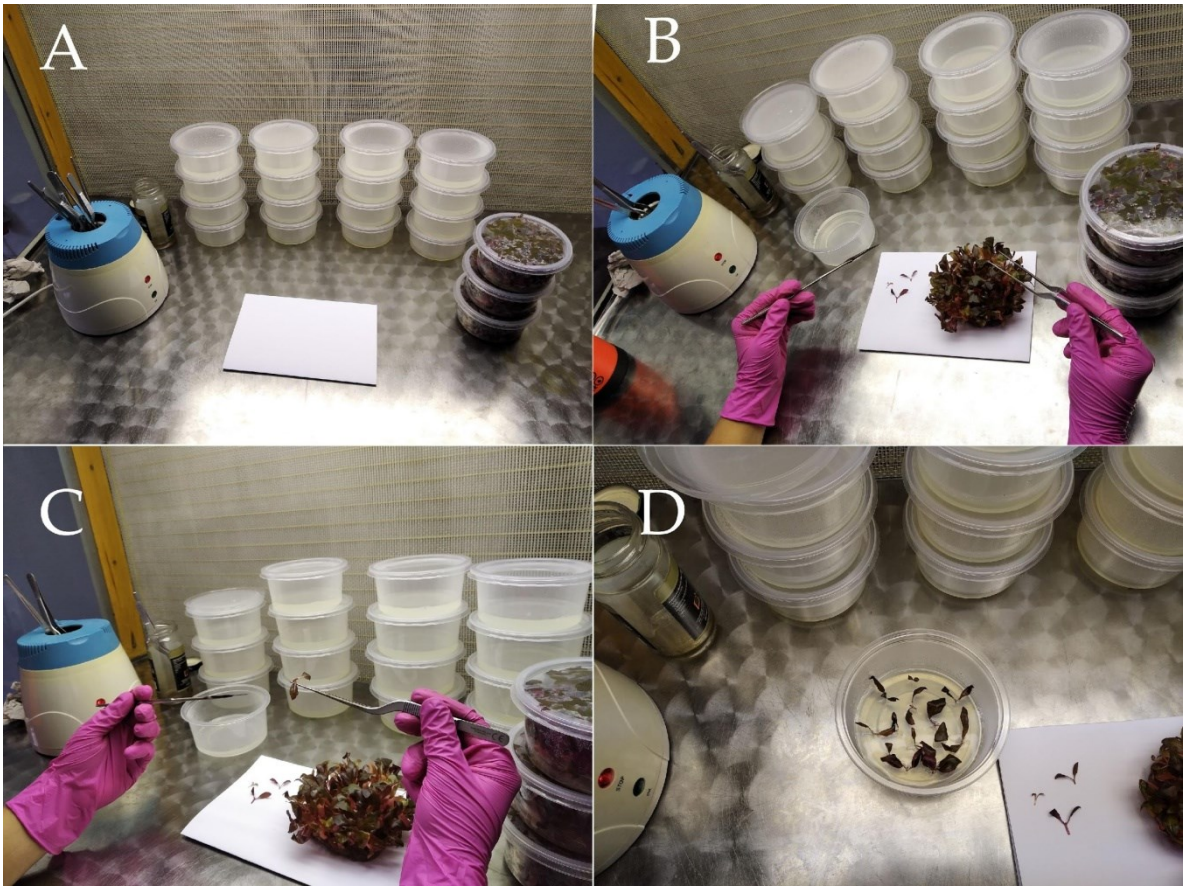

Figure 1. Workplace organization. (A) Location of cups with plants and medium. (B) Cutting off the explants. (C) Selecting explants. (D). Explants placement in medium.

Source: own elaboration.

The duties of employees during the transplanting included: opening a container with mother plants, moving all plants onto a sterile paper plate, cutting an accurate amount of explants (proper fragment of plant for propagation) that can be transplanted without drying too much, opening a container with the medium, transplanting of plants, closing the lid, opening the next one. Repetition of these steps until the total use of all plant material is complete, replacing containers with explants on containers with the medium, removing empty mother plant containers on completion and adding new ones to the laminar flow hood (Figure 1B-1D).

At the end of the day the workplace is cleaned and prepared for work on the next day. Cleaning consists of tweezers and scalpels being removed from the laminar flow hood and placing them on the trolley standing next to the workplace, spraying 70% ethanol solution inside the laminar flow hood and a thorough wiping down. Tweezers and scalpels are replaced with sterile ones the next day, before the start of the working day.

The experiment consisted of examining the work efficiency of five combinations. Firstly – the control combination C1 consisted of an eight-hour work day with plant transplanting, whilst another combination C2-C5 consisted of a six-hour plant transplanting in various systems and two hours of other work activities (Table 1). During these two hours employees were not supposed to transplanting plants. Instead they were doing other necessary activities such as:

preparing medium for the next day, sterilisation, removing contaminated cultures from the growth room and had a 15 minute break.

At the end of each hour the number of plants cut were recorded. The whole 15 minute break took place at the end of the fourth hour of work, 12:45-13:00, within an eight-hour work combination. The break in a six-hour transplanting work combination took place when employees were not working with plant transplanting. During the examination of the six-hour transplanting working day, examination of efficiency consisted of four cases when employees worked: 11 am to 5 pm (C2); 9 am to 11 am and 1 pm to 5 pm (C3); 9 am to 1 pm and 3 pm to 5 pm (C4) and 9 am to 3 am (C5). Table 1 shows the scheme of the work day in different combinations.

Table 1.
Scheme of work day in different combinations

<table>
<tr><th>Work hour</th><th>Combination C1</th><th>Combination C2</th><th>Combination C3</th><th>Combination C4</th><th>Combination C5</th></tr>
<tr><td>9:00-10:00</td><td rowspan="8">plant transplanting with 12:45-1:00 break</td><td>other activities and break</td><td>plant transplanting</td><td rowspan="3">plant transplanting</td><td rowspan="4">plant transplanting</td></tr>
<tr><td>10:00-11:00</td><td rowspan="4">plant transplanting</td><td rowspan="2">other activities and break</td></tr>
<tr><td>11:00-12:00</td></tr>
<tr><td>12:00-1:00</td><td rowspan="3">plant transplanting</td><td>other activities and break</td></tr>
<tr><td>1:00-2:00</td><td rowspan="3">plant transplanting</td></tr>
<tr><td>2:00-3:00</td></tr>
<tr><td>3:00-4:00</td><td>plant transplanting</td><td>other activities and break</td></tr>
<tr><td>4:00-5:00</td></tr>
</table>

Source: own elaboration.

In time series analysis ANOVA Kruskal-Wallis test was used to elaborate data above. P-value is $\alpha = 0{,}05$.

The following hypothesis were adopted:

H0 – there are no significant statistical differences between the employees work performance in each hour and the way the work is organised.

H1 – at least in one of the organization's of work combination, average hourly work efficiency differs significantly from the others.

Apart from this in time series analysis, taking the number of cut plants obtained in the first hour after starting work as 100%, the changes in dynamics of productivity were calculated. The coefficient of variation, as a quotient of the standard deviation and the arithmetic mean of plants produced within each hour was also calculated and in each combination for three repeatition's for ten employees. For determing the number of plants produced in individual hours arithmetic average was used.

The research conducted also allowed for an estimation of Productivity Index PI according to the followed formula:

$$PI = \frac{PRESENT\ PRODUCTIVITY}{BASE\ PRODUCTIVITY}$$

Present productivity is the number of plants that an employee cuts during one hour. The base productivity is the number of plants that each employee should produce in a single hour. PI > 1.0 indicates that productivity is better than the base, planned productivity. PI < 1.0 indicates that productivity is less than planned. Base productivity was determined on the basis of the average highest number of plants produced within a standard 8-hour workday.

The Labour Productivity Index LPI was also calculated. LPI shows the efficiency of services and goods production. It is a ratio between the production of goods and the total number of work-hours or total employment (Freeman, 2008).

$$LPI = \frac{VOLUME\ MEASURE\ OF\ OUTPUT}{MEASURE\ OF\ IN\ PUTUSE}$$

The volume measure of output is the amount of goods and services produced by the workforce. The measure of input use reflects the time and effort of the employees. The measure of labour input is made by the total number of hours worked by all employees.

3. Results

The analysis shows that regardless of the combination, including the control combination C1, the highest work efficiency was between the fourth and sixth hour of the working day. In each combination the best efficiency of work was obtained in the middle of the working day (fig. 2, fig. 3). Even in the C3 combination in which work was started after two hours of completing other tasks, in the fifth hour of work the efficiency of transplanting was as much as 30% higher than in the first hour of work. In combination C2 in which work on plant transplanting started from the third hour of the working day, efficiency in the fifth hour was 25% higher compared to the first hour of work. In C4 and C5 combinations in the fourth working hour, work efficiency was 22.9% higher compared to the first hour, then it gradually declined. It is worth noting that even in the case of a two-hour change of tasks and a return to transplanting, labour productivity at the end of the working day is much higher than in the first or second hour. For example, in the C4 combination, in the eighth hour of the working day, the efficiency was 10% higher than in the first hour of the day, and in the case of the C3 combination 15% higher.

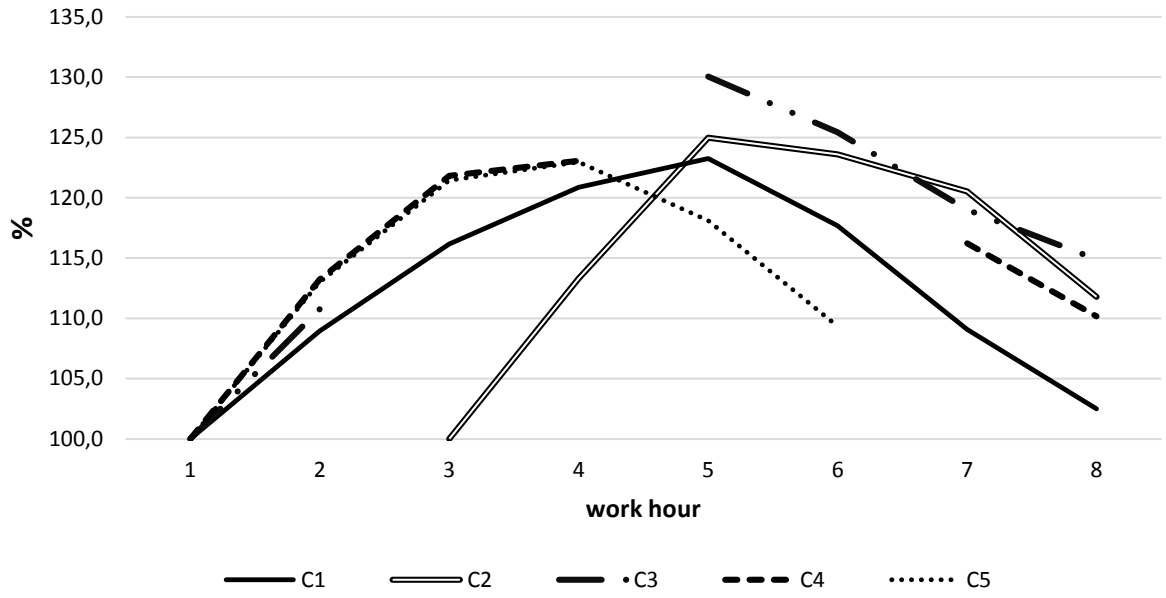

Figure 1. The dynamics of work efficiency during transplanting in five combinations. Work efficiency in the first hour of starting work = 100%.

Source: own elaboration.

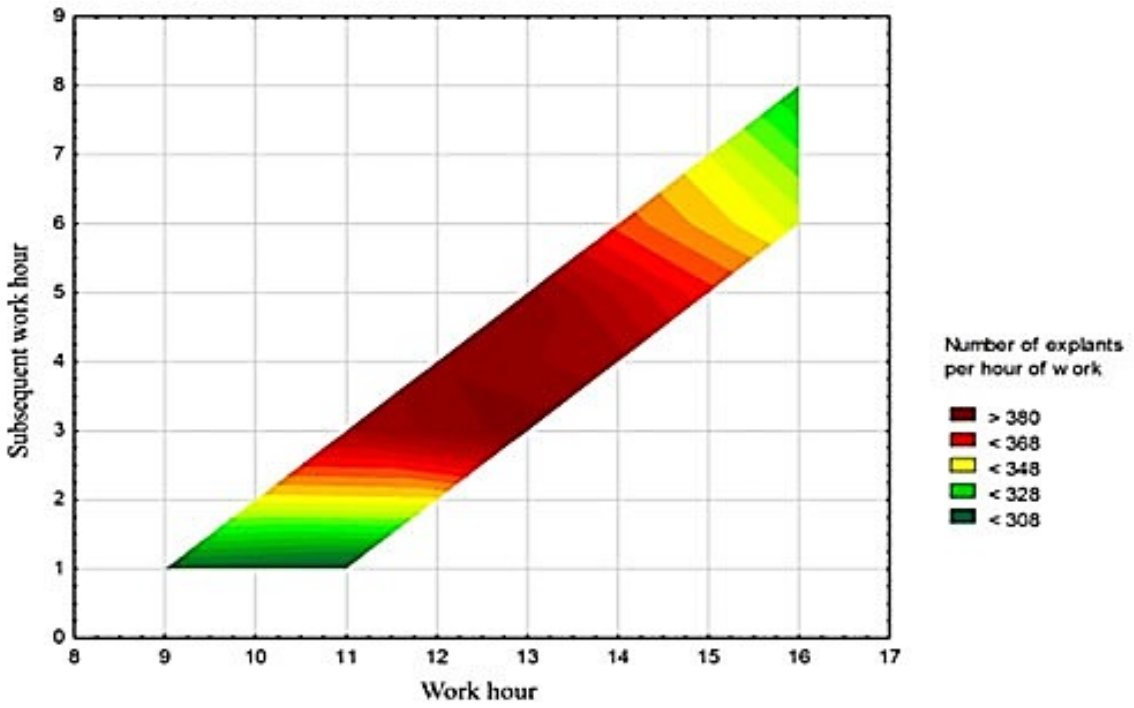

Figure 3. Number of explants per hour of work in subsequent work hour.

Source: own elaboration.

The results presented above were in addition conducted by statistical analysis. The value of all coefficients of variation for the combination C2 to C5 was 58%. The coefficients differed only in decimal values, whilst the coefficient of variation for the combination C1 was 7.1%. The variability for C2 to C5 is higher because work on other duties (other than plant

transplanting) were calculated as '0'. However, regardless of the zeros, the coefficient of variation in all combinations was the same.

The analysis showed that regardless of the organization of work during the day, there are no statistically significant differences in work efficiency. Graphic presentation of the phenomenon described is shown in figure 4. The p-value calculated for individual combinations was 0.9595, whilst the value of statistics H = 0.3029. Because p-value was higher than the assumed significance level $\alpha = 0.05$ therefore, the hypothesis 0 (H0) which stated there are no significant statistical differences between the employees work performance in one hour and the adoption of the way the work is organized.

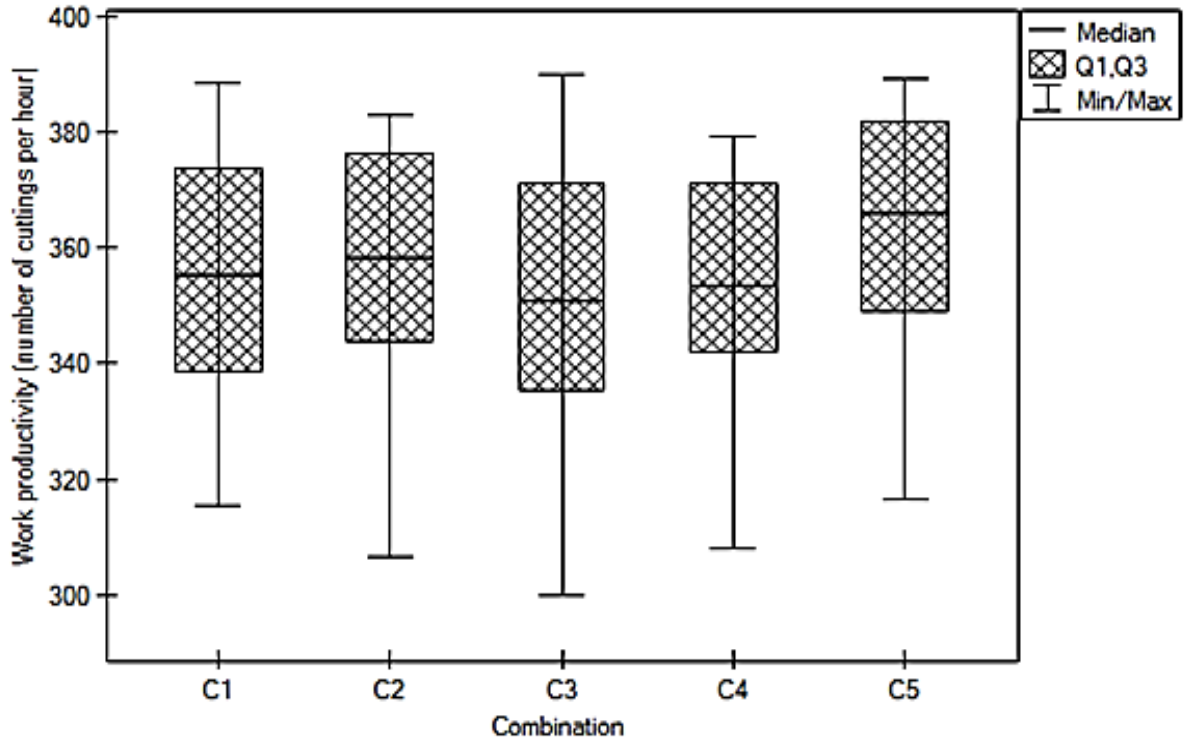

Figure 4. Hourly work efficiency and the work organization during the day based on the Kruskal Wallis ANOVA test*.

Source: own elaboration.

An examination was also conducted into which hour of work employees achieved the highest productivity (highest number of plants) in the control combination C1. Employees gained the highest productivity in the fifth hour, which resulted in 388.67 plants. This result was obtained after just 15 minutes of break from plant transplanting. This number of plants was used as the base productivity for further calculations concerning the Productivity Index. Among all combinations the largest number of plants 389.33 was gained in the fourth hour of work in C5, whilst the worst result, 294.90 plants, was obtained in the first hour in combination C3 (fig. 5).

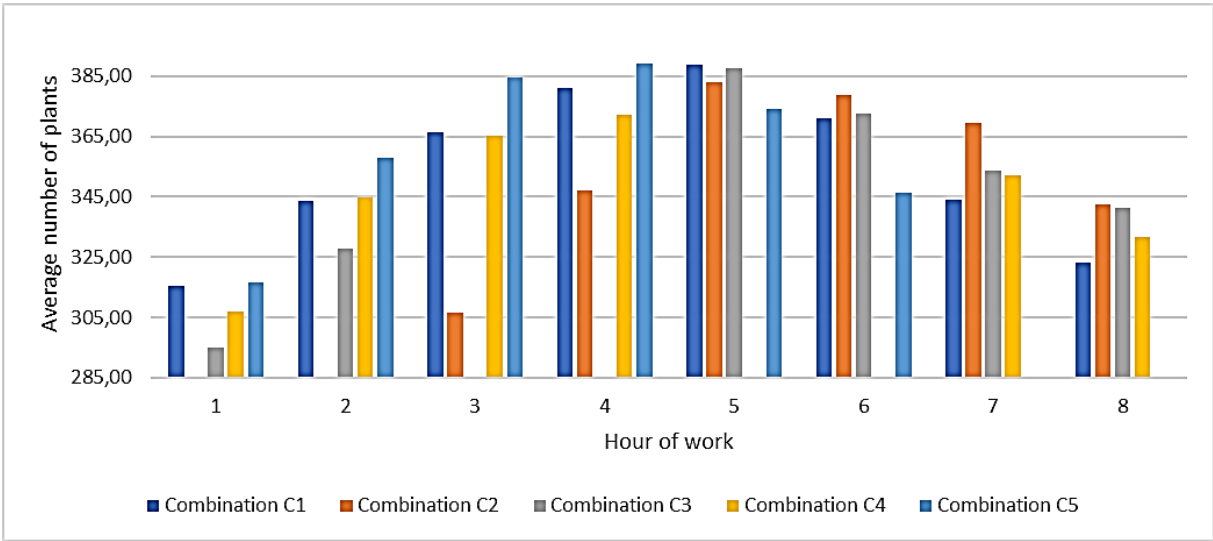

Figure 5. Arithmetic average number of plants produced in individual hours.

Source: own elaboration.

Exploring the Productivity Index the highest result for combination 1, 2 and 3 was in the fifth hour. A slight difference was observed in combination 4 and 5 where the highest PI was in the fourth hour. Whereas the lowest Productivity Index was obtained in the first hour of combination 3 and it was 0.76. In all combinations the Productivity index increased after the first hours to the middle hours of transplanting, after which it began to decrease (fig. 6).

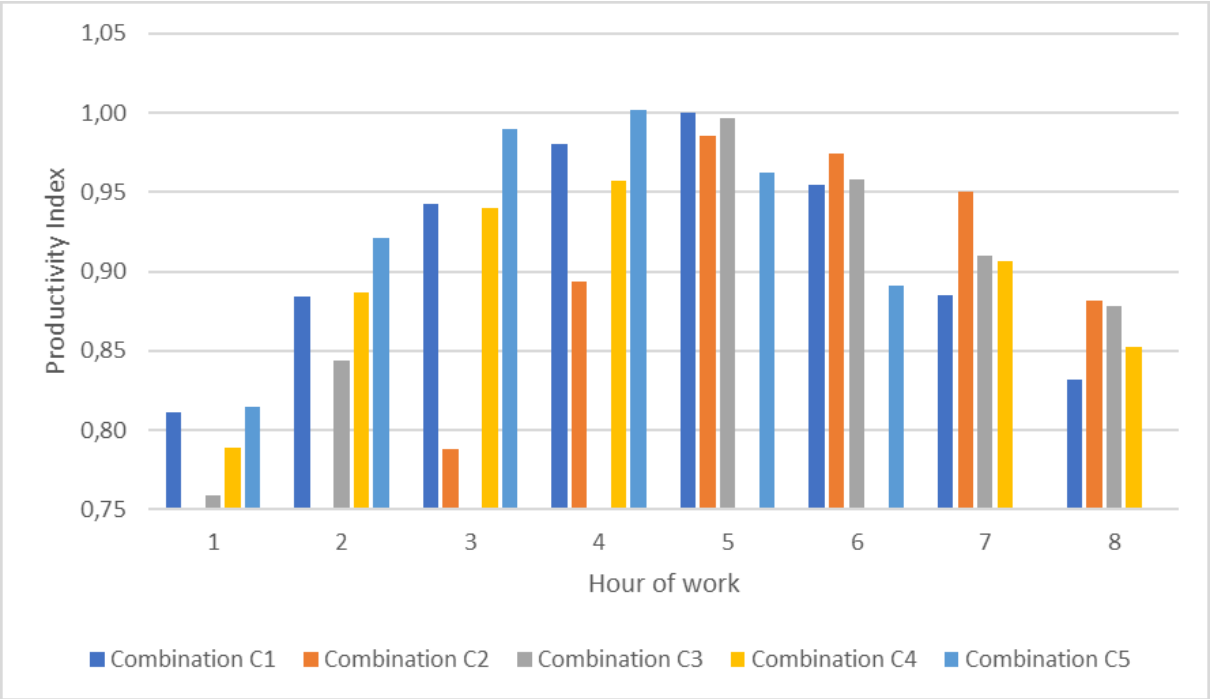

Figure 2. Productivity Index for combination C1-C5.

Source: own elaboration.

The Labour Productivity Index is a great tool used to indicate production efficiency per unit of time. In this study the most effective combination that occurred was C5. Starting the working day with six hours of plant transplanting resulting in LPI 361.44. This means that the average number of plants produced each hour in C5 was 361. The worst LPI was in C4 which was 345.42. A similar result was in combination 3. Disrupting plant transplanting procedures with other activities in combination C3 and C4 during work day leads to a decline in productivity (fig. 7).

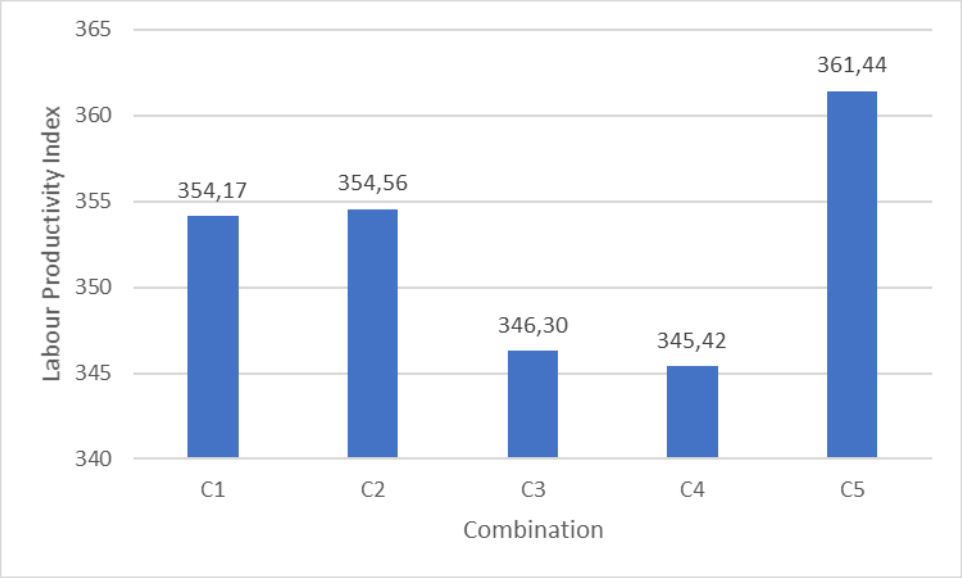

Figure 3. Labour Productivity Index (LPI) reffering to five combination in experiment.
Source: own elaboration.

4. Discussion

Nowadays, when competition among companies is big, new innovative solutions are implemented to increase performance and profits. Because robots and computer programs still can not replace many human activities it is important to find solutions enhancing human productivity. In our study the proposal of six-hours work on the main task during an eight-hour workday was proposed. The study showed that LPI was the biggest when employees spent their first six hours of work on the main task and a further two hours were reserved for other duties. It suggests focusing on the main task in shorter, non-disrupted time which brings better effects. There is a trend for shortening the working day in the corporate environment, especially in offices. It is said to have a positive influence on work by reducing work time but there is little scientific research on its effects. Studies available show a reduction of productivity during extended working hours. It is supported by reliable measurements that show working overtime brings lower productivity. Shepard and Clifton (2000) indicated that in 18 manufacturing

industries overtime lowered average productivity. Similar results can be found across a number of industries. On average a 2.4% decrease in productivity was observed when a 10% increase in overtime was introduced. Working too many hours can lead to mental and physical problems, especially cardiovascular, diseases (Bosma et al., 1997; Stansfeld, Candy, 2006; Street, Lacey, 2018). Mental problems may be related to lower productivity. A good mental condition and avoiding stress can be essential for high performance at work. Street and Lacey (2018) showed that employees of a mining company in Queensland experienced stress during work have 19% lower productivity than employees who did not feel stress at work. So working less hours and in a good atmosphere can truly influence good performance in a company. On the contrary Collewet and Sauermann (2017) proved through an experiment on a call centre company that call quality does not decrease with growth of worked hours during the day. What is more it slightly improves.

Research on productivity should also be supported by the assessment of the reduction of labour costs. As mentioned in the literature review, the workforce can even absorb 60% of the total cost of production. There is a possibility of the reduction in this significant cost through proper workday organization and in this paper the proposal of such a solution was proposed. Our study proved that the middle of the working day is the most effective. This is a signal that during this time the most demanding task can be entrusted to the workers. The effect of higher efficiency in the middle of the day can be explained by assuming that just at the beginning of work the employee needs some time to increase their own work efficiency. In the next stage there is maximum efficiency moment. When employees sense the end of the working day efficiency decreases. A similar dependence was described by Bryson and Forth (2007) but over a period of a week. Monday and Friday occurred to be the less effective days of the week. On these days the smallest number of hours during the workday were really spent on work. Whereas on the middle days of the week, performance was the highest. The reasons for such similarities during weekly and daily changes in productivity are probably the same and are caused by free time after work and weekend rest. At the start of work in daily and weekly routines, rested people need time to re-gain the special co-ordination required to perform tasks which are often lost after rest time. Also similarly, faced with the feeling of the weekend approaching people focus more on plans for entertainment rather than on high performance at work.

5. Conclusions

1. The middle of the workday is characterised by the highest efficiency, so at this time of the workday the most demanding tasks should be entrusted. At the beginning and at the end of work, when performance is lower, less demanding tasks can be completed. These can include employees performing various duties, work in tissue culture laboratories should be organised as mentioned above.
2. In an eight hour workday combination the best productivity is gained in the fifth hour just after a fifteen minute break. The lowest productivity is gained when the main task (plant transplanting) is interrupted a by other duties for two hours.
3. The highest productivity is achieved in a combination when the main task was completed for six hours (starting from the first hour) during an eight hour working day.
4. However, it should be emphasized that hypothesis H0 which stated that there are no significant statistical differences between the employees work performance in each hour and the way the work is organized was confirmed.

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